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Social Economics of Childhood Glucocorticoid Stress Response and Health

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KEY WORDS stress; health; family; socioeconomic conditions; Caribbean; cortisol; salivary immunoassay

ABSTRACT This study examines socioeconomic conditions, psychosocial stress, and health among 264 infants, children, adolescents, and young adults aged 2 months to 18 years residing in a rural Caribbean village. Fieldwork was conducted over a 9 year period (1988–1996). Research methods and techniques include salivary cortisol radioimmunoassay (N = 22,438), systematic behavioral observations, psychological questionnaires, health evaluations, medical records, informal interviews, and participant observation.

Analyses of data indicate complex relations among socioeconomic conditions, stress, and health. Household income, land ownership, parental education, and other socioeconomic measures are weakly associated with child illness. There is no evidence that apparent material benefits of high socioeconomic status—such as improved housing, diet, work loads, and access to private healthcare—have important direct effects on child health in this population. However, social relationships, especially family environment, may have important effects on childhood psychosocial stress and illness. Abnormal glucocorticoid response profiles, diminished immunity, and frequent illness are associated with unstable mating relationships of parents/caretakers and household composition. We suggest that family relationships and concomitant stress and immunosuppression are important intermediary links between socioeconomic conditions and child health. Am J Phys Anthropol 102:33–53, 1997. © 1997 Wiley-Liss, Inc.

Studies of socioeconomic conditions (SECs) and health in Western societies indicate consistent trends. Income, occupation, and education are associated with a wide variety of illness as well as rates of morbidity and mortality (Marmot et al., 1987; Illsley and Baker, 1991; House et al., 1991; Margolis et al., 1992). Wealthy, well-employed, highly educated people are healthier than those less fortunate.

However, the obvious explanation of a better physical environment—improved housing, work conditions, nutrition, health care, and reduced exposure to pathogens and poisons—is insufficient (Marmot et al., 1991; Ellis, 1994). The specific mechanisms underlying the pervasive association between SECs and health are surprisingly uncertain. Psychosocial stress[1] and associ-

[1]*Stress* or *stressful* are terms that have elusive meanings; a recent review called the attempt to define stress "an exercise in futility" (Levine et al., 1989:341). Some of the confusion may be semantic, but much of the problem originates with the misconception that there is a uniform, general physiological response to a variety of "stressors" that perturb the organism (see critiques by Mason, 1971; Levine et al., 1989). In this paper we attempt to avoid this quagmire by referring to glucocorticoid stress response as a specific, measurable phenomenon. We believe an evolutionary perspective of physiological responses and their effects may help clarify the definitional issue. We hypothesize that human

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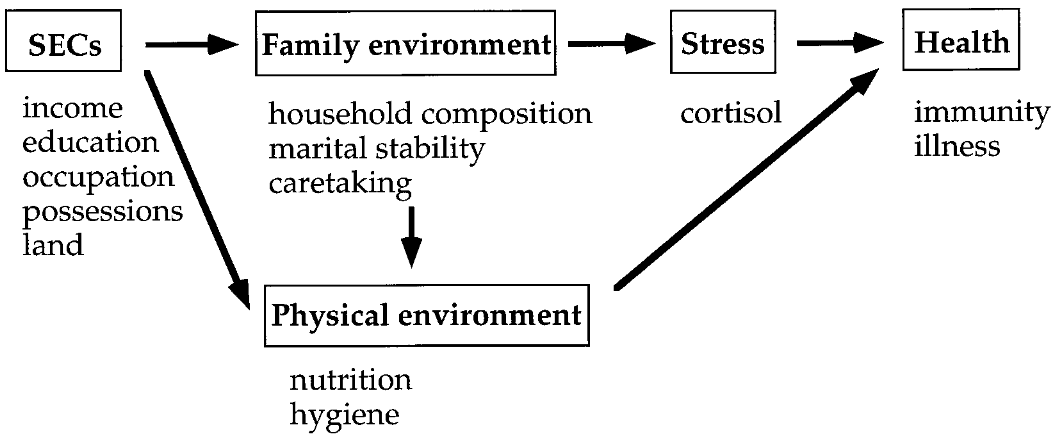

Fig. 1. Hypothesized relations among SECs, family environment, stress, and health.

ated immunosuppression are possible intermediaries (Adler et al., 1994; Kiecolt-Glaser et al., 1988, 1994; Black, 1994).

Investigation of relations among SECs, psychosocial stress, and health has been hampered by the lack of noninvasive techniques for measurement of stress hormones. Frequent collection of plasma samples in nonclinical settings is not feasible. The development of saliva immunoassay techniques (Hiramatsu 1981; Riad-Fahmy et al., 1983), however, presents new opportunities for stress research (Kirschbaum et al., 1992). Saliva is relatively easy to collect and store, especially under adverse field conditions faced by anthropologists (Ellison, 1988).

Here we investigate relations among SECs, family environment, glucocorticoid stress response, and child health in a rural village (Bwa Mawego[2]) on the east coast of Dominica. We suggest that SECs affect child health indirectly via their influence on patterns of family organization and consequent levels of psychosocial stress (Fig. 1). Analyses of data indicate that children living in households with intensive, stable caretaking usually have moderate levels of stress hormones and a low frequency of illness. Children living in households with nonintensive, unstable caretaking are more likely to have high, low, and/or unusually variable levels of stress hormones and a high frequency of illness.

STRESS RESPONSE MECHANISMS AND THEORY

Physiological response to environmental stimuli that are perceived as stressful is modulated by the limbic system (amygdala and hippocampus) and basal ganglia which interact with the sympathetic and parasympathetic nervous systems and two neuroendocrine axes: the sympathetic-adrenal medullary system (abbreviated as SAM) and the hypothalamic–anterior pituitary–adrenal cortex system (abbreviated as HPA). The SAM and HPA systems affect a wide range of physiological functions in concert with other neuroendocrine mechanisms and involve complex feedback regulation. The SAM system controls the catecholamines norepinephrine and epinephrine (adrenalin). The HPA system regulates glucocorticoids, primarily cortisol (for reviews see Rose, 1980; Gray, 1987; Sapolsky, 1992a,b; McEwen, 1995). These two major neuroendocrine systems are interdependent (Axelrod and Reisine, 1984) but have distinct physiological effects and response sensitivities to different stressors.

Cortisol is a key hormone produced in response to physical and psychosocial stressors (Mason, 1968; Selye, 1976). Cortisol modulates a wide range of somatic func-

psychosocial stress responses have evolved to be sensitive to conditions for which adaptive contingencies exist (i.e., conditions to which individuals benefit from changing their behavior in ways that are influenced by physiological/neurological effects of stress responses; see also footnote 3).

[2]Pseudonyms for the community and individuals are used for confidentiality.

tions, including energy release (e.g., stimulation of hepatic gluconeogenesis in concert with glucagon and inhibition of the effects of insulin), immune activity (e.g., downregulation of inflammatory response and the cytokine cascade), mental activity (e.g., alertness, memorization, and learning), growth (e.g., inhibition of growth hormone and somatomedins), and reproductive function (e.g., inhibition of gonadal steroids, including testosterone). These complex, multiple effects of cortisol muddle understanding of its adaptive functions. The demands of energy regulation must jibe with those of immune function and so forth. Mechanisms for localized targeting (e.g., glucose uptake by active vs. inactive muscle tissues and neuropeptide directed immune response) provide fine tuning of the above general physiological effects. Cortisol regulation allows the body to respond to changing environmental conditions by preparing for specific short-term demands (Mason, 1971; Munck et al., 1984).

These temporary beneficial effects of glucocorticoid stress response, however, are not without costs. Persistent activation of the HPA system is associated with immune deficiency, cognitive impairment, inhibited growth, delayed sexual maturity, damage to the hippocampus, and psychological maladjustment (Ader et al., 1991, 1995; Dunn, 1989, 1995; Geiser, 1989; Glaser and Kiecolt-Glaser, 1994). Chronic stress may diminish cellular energy (Ivanovici and Wiebe, 1981; Sapolsky, 1986, 1991) and produce complications from autoimmune protection (Munck et al., 1984; Munck and Guyre, 1991). Stressful life events—such as divorce, death of a family member, change of residence, or loss of a job—are associated with infectious disease and other health problems (Cohen, 1988; Cohen et al., 1989; House et al., 1988; Kaplan, 1991; Herbert and Cohen, 1993; Maier et al., 1994; Rabkin and Steuning, 1976).

Current psychosocial stress research suggests that cortisol response is stimulated by uncertainty that is perceived as significant[3] and for which behavioral responses will have unknown effects (Fredrikson et al., 1985; Levine, 1993; Haggerty et al., 1994; Kirschbaum and Hellhammer, 1989, 1994). That is, important events are going to happen, and the child does not know how to react but is highly motivated to figure out what should be done. Cortisol release is associated with unpredictable, uncontrollable events that require full alert readiness and mental anticipation. In appropriate circumstances, temporary moderate increases in stress hormones (and associated neuropeptides) may enhance mental activity for short periods in localized areas, hence improving cognitive processes for responding to social challenges (cf. Coe et al., 1985; Martinez, 1986; Breier et al., 1987; Martignoni et al., 1992; McEwen and Sapolsky, 1995). Mental processes unneccesary for appropriate response may be inhibited, perhaps to reduce external and internal "noise" (Servan-Schreiber et al., 1990; cf. Wolkowitz et al., 1989, 1990; Newcomer et al., 1994).

Relations between cortisol production and emotional distress, however, are difficult to assess because of temporal and interindividual variation in HPA response (Tennes and Mason, 1982; Hubert and de Jong-Meyer, 1989; Young et al., 1991; Kagan, 1992; Nachmias et al., 1996). Habituation may occur to repeated events for which a child acquires an effective mental model. Attenuation and below normal levels of cortisol may follow a day or more after emotionally charged events. Chronically stressed children may develop abnormal cortisol response, possibly via changes in binding globulin levels, and/or reduced affinity or density of glucocorticoid or CRH/vasopressin receptors in the brain (Fuchs and Flugge, 1995). Early experience—such as perinatal stimulation of rats (Meaney et al., 1991), prenatal stress among rhesus macaques (Coe et al., 1989, 1992; Schneider et al., 1992; Clarke, 1993), and prenatal trauma (Magnano et al., 1992; Takahashi, 1992) and sexual abuse (De Bellis et al., 1994) among humans—may permanently alter HPA response (cf., Insel, 1990). And personality may affect HPA response (and vice versa), because children with inhibited temperaments tend to have higher cortisol levels than extroverted children (Kagan et

[3]In evolutionary terms, *significant* is used in the sense of a fitness-altering event. As a product of natural selection, cognitive processing of information in regard to stress involves assessment of fitness consequences of potential stressors. Positive or negative effect is irrelevant. The criterion is whether stimulation of a stress response would be advantageous (fitness-maximizing).

al., 1988; cf. Flinn and England, 1995; Gunnar et al., 1995; Hertsgaard et al., 1995; Nachmias et al., 1996).

Further complications arise from interaction between HPA stress response and a wide variety of other neuroendocrine activities, including modulation of catecholamines (SAM), corticotropin-releasing hormone (CRH), melatonin, testosterone, serotonin, β-endorphins, cytokines, and enkephalins (Axelrod and Reisine, 1984; De Kloet, 1991; Sapolsky, 1992a; Saphier et al., 1994). Changes in cortisol for energy allocation and modulation of immune function may be confused with effects of psychosocial stress. Oxytocin and vasopressin intracerebral binding sites are associated with familial attachment in mammals (Insel, 1992; Winslow et al., 1993) and may influence distress involving caretaker-child relationships. Concurrent monitoring of all these neuroendocrine activities would provide important information about stress response but is not possible in a nonclinical setting with current techniques.

In sum, assessment of relations between emotional states and cortisol is complex, requiring many components: longitudinal monitoring of hormone levels; control of extraneous effects from physical activity, circadian rhythms, and food consumption; knowledge of individual differences in temperament, experience, and perception; and awareness of cultural context. Anthropological research that integrates biology and ethnography is particularly well suited to these demands (e.g., Armelagos et al., 1992; Brown, 1981, 1982; Dressler et al., 1988; Ellison, 1994; Goodman et al., 1988; Hanna et al., 1986; James et al., 1989; Pollard, 1995; Pearson et al., 1993; Shell-Duncan, 1993, 1995; Panter-Brick et al., 1996; Werner, 1985). Physiological assessment in concert with ethnography and coresidence with children and their families in a small village over a 9 year period can provide intimate, prospective, naturalistic information unavailable to clinical studies.

MATERIALS AND METHODS

Research design

Longitudinal monitoring of cortisol in a natural (nonclinical) environment was used to identify specific psychosocial causes and consequences of childhood stress. Data analyses examine both long-term (cumulative) and short-term (day-to-day, hour-by-hour) associations among cortisol levels, family composition, socioeconomic conditions, behavioral activities, immune response, and illness.

Variables and measures are as follows. Physiological stress response was assessed by radioimmunoassay (RIA) of cortisol levels in saliva. Analyses examine mean values, variation, and day-to-day and hour-by-hour profiles of standardized (circadian time control) cortisol data. Family composition was assessed by age, sex, genealogical relationship, and number of individuals in the caretaking household. Socioeconomic conditions included household income, material possessions, land ownership, occupations, and educational attainment. Caretaking attention was assessed by frequencies and types of behavioral interaction, informant ratings of caretaking that children received, and informant interviews. Personality and temperament were assessed by culturally appropriate versions of EAS (Buss and Plomin, 1984) and five-factor (Goldberg, 1992, 1993) instruments, informant (peers, parents, teachers, neighbors) interview, and behavioral observation. Immune response was assessed by RIA of neopterin and interleukins-1 and -8, turbidimetric immunoassay of secretory-immunoglobulin A, and microparticle enzyme immunoassay of microglobulin β_2 from saliva samples. Health was assessed by observed type, frequency, duration, and severity of medical problems (diarrhea, influenza, common cold, asthma, abrasions, rashes, etc.), informant (parents, teachers, neighbors) ratings, medical records (including weight measurements) from the public healthcare system, and physical examination by a medical doctor. In this study, the quantitative measure of health used is percentage of days ill, the proportion of days that a child was observed (directly by researchers) with common benign temporary infectious diseases (89% were URTIs—e.g., rhinovirus, adenovirus, and influenza; 6% were diarrheal; 5% were miscellaneous indeterminate—e.g., febrile without other symptoms). Daily activities and emotional

states were assessed from caretaker and child self-report questionnaires, systematic behavioral observation (focal follow and instantaneous scan sampling), and participant observation. Multiple sources of information were cross-checked to assess reliability (Bernard et al., 1984).

The primary focus of this study is on relations among percentage of days ill, socioeconomic conditions, family composition, and stress. Caretaking attention, temperament, immune function, daily activities, and emotional states are analyzed as secondary or control variables; they are presented in more detail in other publications.

Study site

Bwa Mawego is a rural village located on the east coast of Dominica. The 780 ± residents live in 206 ± structures/households that are loosely clumped into five hamlets or neighborhoods. The population is of mixed African, Carib, and European descent. The village is isolated because it sits at the dead end of a rough road passable by small trucks except for occasional periods during the rainy season (the road was improved and partially paved in 1991 and 1993). Part-time residence is common, with many individuals emigrating for temporary work to other parts of Dominica or off-island (e.g., seasonal farm work in the United States and Canada). Most residents cultivate bananas and/or bay leaves as cash crops, and plantains, dasheen, and a variety of fruits and vegetables as subsistence crops. Fish are caught by free-diving with spear guns and from small boats (hand-built wooden “canoes” of Carib design) using lines and nets. Land is communally “owned” by kin groups but parcelled for long-term individual use.

Most village houses are strung close together along roads and tracks. Older homes are constructed of wooden planks and shingles hewn by hand from local forest trees; concrete block and galvanized roofing are more popular today. Most houses have one or two sleeping rooms, with the kitchen and toilet as outbuildings. Children usually sleep together on foam or rag mats. Wealthier households typically have “parlors” with sitting furniture. Electricity became available in 1988; during the summer of 1995 about 70% of homes had current, 41% had telephones, 11% had refrigerators, and 7% had televisions. Water is obtained from streams, spring catchments, and runoff from roofs.

The village of Bwa Mawego was appropriate for the study of relations among SECs, family environment, psychosocial stress, and child health for the following reasons: 1) there was substantial temporal and permanent variability among individuals in the factors under study (SECs, family environments, profiles of cortisol response, and child health); 2) the village and housing were relatively open, so behavior was easily observable; 3) kin tended to reside locally; 4) the number of economic variables was reduced relative to urban areas; 5) the language and culture were familiar to the investigator; 6) there were useful medical records; and 7) local residents welcomed the research and were most helpful.

The study involved 264 individuals aged 2 months to 18 years residing in 82 households. This was a nearly complete sample (>95%) of all children living in four of the five village hamlets during the period of fieldwork. Research was conducted during June–August 1988, June–August 1989, May–December 1990, May–August 1992, June–August 1993, December 1993–February 1994, May–August 1994, June–August 1995, and June–July 1996.[4] Cortisol data are from saliva samples collected during July–December 1990, June–August 1992, June–August 1993, December 1993–January 1994, June–August 1994, and July 1995.[5]

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[4]M.V.F. was assisted in the field by Eric Durbrow in 1988, 1989, and 1990; Tomasz Beer, M.D., Ingrid Bozoky, and Carol Ward in 1990; Seamus Decker in 1992, 1993, and 1994; David Tedeschi in 1992 and 1993; Robert Quinlan and Marsha Quinlan in 1993, 1994, and 1996; Frank McCluskey and Charles Keckler in 1996; and Mark Turner in 1993, 1994, 1995, and 1996.

[5]During August–December 1990 saliva was collected twice daily from each child for four 6 day periods. Because saliva must be collected during a limited time period, the study population was divided into two roughly equal halves, with collection periods alternating between them (i.e., 6 days with one-half, then six days with the other; hence saliva was collected for a total of four + four = eight 6 day periods). All-day “focal follows” with hourly saliva collection were conducted with two children to provide more precise information on cortisol variation. During the 1992 field season, I was assisted by two graduate students, and saliva was collected concurrently (each of us took one of three separate routes) from all children during two 6 day periods. During the 1993 and 1994 field seasons, I was assisted by three graduate students, and saliva was collected concurrently from all children during six 6 day periods. All-day focal follows with hourly saliva collection were conducted with four children. During 1995 and 1996, saliva was collected three or four times at approximately 2 h intervals from all children over 6 and 3 day periods. Additional all-morning focal follows with hourly saliva collection were conducted with 30 infants and mothers by Mark

Field techniques

Information on socioeconomic conditions, household environment, caretaking attention, temperament, and health was collected by standard ethnographic techniques including interviews, behavioral scans, participant observation, and questionnaire instruments. These methods are described in more detail in other publications (Flinn, 1988; Quinlan, 1995).

Data on physiological stress response were derived from RIA of saliva samples (see below). Saliva was collected by three routines. The primary routine was a twice-daily collection in which an anthropologist and research assistant walked set routes from house to house, once in the morning (5:30 AM to 9:00 AM) and once in the afternoon (3:00 PM to 6:30 PM). Most (16,652 of 22,438) saliva samples were collected this way. The second routine collected saliva three or four times at 2 h intervals beginning in the early morning and ending in the early afternoon (2,362 of 22,438). The third routine used a "focal follow" technique in which the child was observed from dawn until early afternoon or evening or the infant was observed from dawn until early afternoon, both with hourly saliva samples (3,424 of 22,438). Saliva samples from some parents and other caretakers were collected at the same time as their children.

Our saliva collection protocol was as follows. First, each child rinsed her/his mouth with fresh water. At this point, children were checked for oral bleeding. Both food and blood contamination may affect the integrity of samples (Ellison, 1988). Next, children were given one-quarter to one-half stick of Wrigley's gum (spearmint) to stimulate saliva production. After the gum was chewed for about 1 min and the sugar swallowed saliva was deposited in disposable plastic cups for about 3 min. For infants, saliva was collected by swabbing with cotton rolls (Turner, n.d.). Approximately 4 ml of saliva was pipetted into labeled (name, date, time, number) polystyrene test tubes and preserved using sodium azide and refrigeration. Analysis of cortisol levels requires precise information on time of collection, time of waking from sleep, and individual sleep schedule because there is a circadian pattern to cortisol release (Fredrikson et al., 1985; Van Cauter, 1990). Some hourly samples were taken for finer-grained analysis of temporal fluctuation in cortisol levels. Daily activity, emotional state, and health questionnaires were administered concomitant with saliva collection (see below).

Children readily acclimated to the collection procedure. However, introverted and excitable children tended to have cortisol levels that were higher than normal for the first few days of saliva collection. Multiple samples (more than 50 days of morning and afternoon samples over several years) from each child provided a more effective indication of stress response than a single collection design.

Laboratory procedures and data analysis

Cortisol levels in saliva samples were determined by RIA techniques. Salivary cortisol is a reliable measure of adrenal cortical function (Hiramatsu, 1981; Umeda et al., 1981; Vining et al., 1983; Bolufer, 1989; Kirschbaum et al., 1992). All samples were analyzed at the Ligand Assay Laboratory at the University of Michigan Hospitals.

Our RIA protocol was as follows: 1) saliva tubes were decapped and centrifuged at 2,400 rpm for 10 min at 6°C; 2) tubes were placed in a rack for an automatic pipetting robot, which pipetted 200 µl of saliva from each sample tube into receiver tubes from DPC ^{125}I cortisol solid phase radioimmunoassay kits, and each sample was duplicated; 3) radioactive label was added and tubes vortexed; 4) receiver tubes were placed in 37°C water baths for 45 min, after which they were aspirated (twice); 5) receiver tubes were run through a gamma counter; and 6) data from the counter were analyzed with a statistical program (StatLIA). Six standards

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Turner in 1994 and by Mark Turner and Mark Flinn in 1995.

The half-life of cortisol is about 1 h. However, we have discovered that this is dependent on several factors, including level of physical exertion (activity shortens the half-life) and the type of stressor (some psychosocial stressors seem to involve longer-term release patterns). Hence, there is not an easy answer to this important issue. The affect of family interactions on cortisol levels is probably accentuated in our sample because most of the samples were collected during time periods (early morning at home, late afternoon at home) that are likely to involve family interactions. Hence, many of the observed traumatic family interactions occurred within 1–2 h of saliva collection. We are currently investigating such time effects in more detail.

(.2–50 µg/dl) diluted 8:1 were used to determine the assay curve. B/B0 ratios, covariance of duplicates, and interassay variation using these techniques are of high quality (e.g., covariance of duplicates for 1993–1995 samples averaged 1.9%; covariance of interassay duplicates averaged 4.1%).

Cortisol release follows a circadian pattern, with highest levels around waking up in the morning, diminishing to low levels during evening hours and a nadir just before or during sleep. For example, mean cortisol levels when children had been awake for 10 min was .578 µg/dl, for 2 h it was .222 µg/dl, and for 8 h it was .071 µg/dl. To control for time (circadian) effects, raw cortisol measures were standardized by 5 min time intervals from wake-up time.[6] For each time interval, mean values and standard deviations were computed.

Standardized values were generated as time-controlled measures of cortisol response as with the following hypothetical example: the mean cortisol level of children who have been awake for 60 min is .3 µg/dl with standard deviation of .1 µg/dl. A cortisol measure of .4 µg/dl from this time period would have a standardized value of 1.0 (i.e., .4 µg/dl is one standard deviation (.1 µg/dl) from the average (mean) value of .3 µg/dl). This procedure allows comparison of cortisol values from saliva collected at different times. All cortisol data presented in this paper are time standardized.

During saliva collection, children and their caretakers were asked a series of questions concerning what activities the child did that day and how the child felt during these activities. This self-report and caretaker-report information on daily activities was compared with behavioral observation data. Health evaluations were also conducted daily during saliva collection. If illness is indicated, body temperature was checked using an oral thermometer. Blood pressure was measured once a week.[7]

Most individuals exhibited a slight rise (about .01 µg/dl at lunch, or 13%) in cortisol levels after eating a meal or drinking caffeinated beverages. This postprandial rise was most significant for the midday meal. Data were not adjusted for eating and caffeine intake because very few samples were taken during lunchtime, the effect is small, and the occurrence of eating and caffeine intake were presumed random with regard to hypotheses tested. Individuals commonly have small elevations in cortisol levels during midday, usually in association with potential minor stressors (Holl et al., 1984).

Some individuals show a rise in cortisol levels during and shortly after intensive physical exertion (e.g., carrying heavy loads of wood, water, bananas, or bay leaf). Physical exertion involving social interaction, such as competitive sports, is associated with more substantial elevation of cortisol levels, particularly for males. Data were not adjusted for physical activity because only a small proportion of samples was collected when children were physically exerted, it was difficult to determine how exerted children were, and such activities are presumed random with regard to hypotheses tested. Because general activity levels are associated with cortisol, this presents a confounding effect. Some children may have increased cortisol response when they are healthy and active and have abundant energetic resources compared to when they are inactive and have depleted energy reserves (although severe food deprivation can result in elevated cortisol levels).

RESULTS AND DISCUSSION

Family environment is a key intermediate variable connecting socioeconomic conditions and health

Associations between SECs and the frequency of child illness in Bwa Mawego are weakly positive (Fig. 2). Land ownership is the only SEC significantly associated with frequency of illness. This is surprising, given that children from economically advantaged

[6]Wake-up time is used because individuals have different sleep schedules; some children arise habitually at 5:30 AM, whereas others sleep until 7:00 or later. Hence, circadian time controls must include individual differences and are most appropriately based on wake-up time rather than absolute time (Flinn et al., 1992). Five minute time intervals are necessary because of the quick drop in cortisol levels during the morning (approximately a 1 hour half-life; from about .6 µg/dl 30 min after waking to .22 µg/dl at 120 min after waking). This technique requires a large number of samples (>100 samples per time interval).

[7]Blood pressure was measured during the 1990 and 1992 field seasons only.

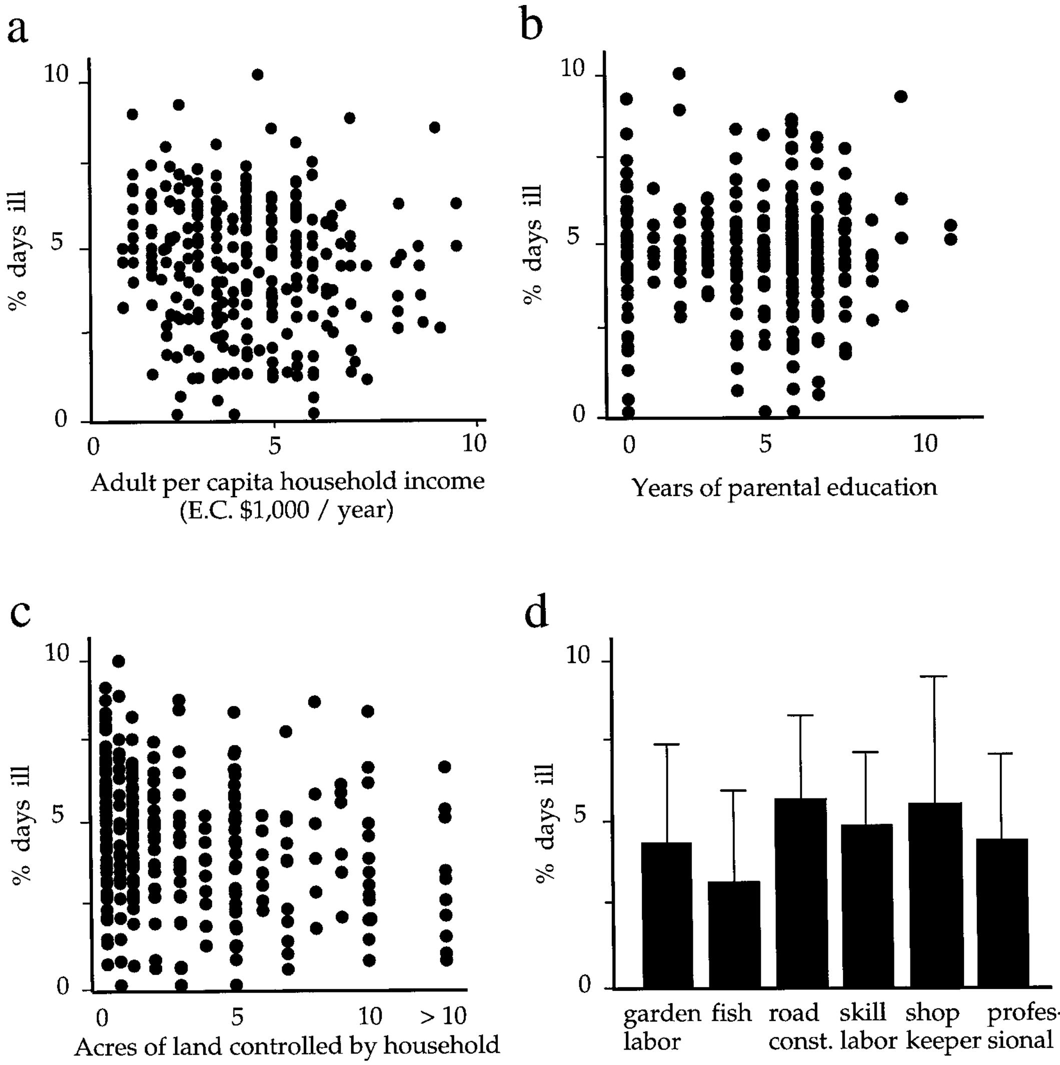

Fig. 2. SECs were weakly associated with frequency of illness (primarily upper respiratory infections with visible symptoms—runny nose, sore throat, cough, and/or fatigue) during 11 months of direct observation. R = 0.18 (N.S.), 0.24 (N.S.), and 0.31 ($P < .05$) for (**a**) income, (**b**) education, and (**c**) land, respectively. Vertical lines represent 95% confidence intervals for (**d**) occupation.

(high income, occupation, education) families typically enjoyed a more varied diet, access to medicines bought in town, expensive clothes (e.g., better shoes for protection from foot lacerations), better bedding, electricity for lighting and refrigeration, and better toilet and food-preparation facilities. But these material benefits apparently did not significantly affect risk of illness.

There are many possible reasons why associations between SECs and health might not be as strong in Bwa Mawego as in industrialized populations. Wealthy families may not have a healthier diet (e.g., they eat more processed food such as tinned meat) or neighborhood environment (wealthy and poor houses are intermingled). Wealthy families may exercise less (e.g., less physical labor such as carrying water), and adults may drink more alcohol and smoke more cigarettes (because they have cash to buy them). Wealthy and poor children may be

TABLE 1. Household composition (primary caretakers) of study sample

	Children in sample							
	1990–1991		1992		1993–1994		1995	
Household composition	N	%	N	%	N	%	N	%
Biparental (nuclear)	69	33.0	81	34.9	86	36.1	73	35.8
Biparental, father absent >50%	24	11.5	14	6.0	16	6.7	14	6.8
Single mother	19	9.1	27	11.6	27	11.3	22	10.8
Single mother + kin	24	11.5	28	12.1	25	10.5	22	10.8
Single father	3	1.4	2	0.9	1	0.4	1	0.4
Grandmother	26	12.4	28	12.1	29	12.2	21	10.3
Grandparents	14	6.7	16	6.9	16	6.7	16	7.8
Other kin (aunt, cousin)	4	1.9	6	2.6	6	2.5	6	2.9
Mother + stepfather without kids	3	1.4	3	1.3	3	1.3	3	1.5
Mother + stepfather with kids	19	9.1	22	9.5	24	10.1	21	10.3
Nonrelative	7	3.3	5	2.2	5	2.1	5	2.4

equally exposed to pathogens and environmental hazards (because they intermingle and roam the community). Healthcare is public and available equally to all.

An alternative explanation for the pattern of associations between SECs and frequency of illness in Bwa Mawego involves family organization. Acquisition and control of socioeconomic resources is a fundamental human motivation that has important effects on family relationships. The wide cross-cultural range of human patterns of mating and residence of kin are associated with subsistence activities (Murdock, 1949; Irons, 1983; Flinn and Low, 1986; cf. Emlen, 1995). Among Caribbean populations, SECs are strongly associated with family organization (Clarke, 1957; Rodman, 1971; Flinn, 1986; Smith, 1988). Temporary and migratory wage labor foster unstable mating relationships and multigenerational matrilocal residence and caretaking. Land ownership is associated with stable mating relationships, biparental caretaking, and enhanced agnatic kin relationships (Flinn, 1992).

Children in Bwa Mawego live in a variety of family environments. Table 1 provides information on frequencies of 13 general types of household composition of the study sample during the field seasons of 1990–1991, 1992, and 1993–1994. Household composition in the Caribbean is dynamic; in Bwa Mawego during 1990–1994, 31% of households with children changed composition (category) at least once, and many children (27%) resided in more than one household. *Household* was defined as a physical structure (house) in which a family resides (sleeps, eats meals, stores possessions, etc.). The social and physical reality of caretaking households varied. Most had extensive kin ties to other households, often resulting in a "compound" of neighboring families. Others are more isolated. Other important aspects of a child's family environment may include the parents' marital relations, ties to relatives residing in other households, and use of alcohol by one or more caretakers.

SECs are weakly associated with family environment (Fig. 3). As with frequency of illness, land ownership is the only SEC that is significantly associated with household composition (lower education of grandparents results from their age; schooling was less available in the past).

The pattern of associations between SECs and child illness observed previously (Fig. 2) may result from differences in family environment. Household composition is associated with child illness regardless of SECs (Fig. 4). Children living with nonrelatives, stepfathers + half siblings (stepfather has children by the stepchild's mother), or single parents without kin support were ill more frequently than children living with both parents, single mothers with kin support, or grandparents. A further test of this hypothesis is provided by comparison of step- and genetic children residing in the same households (Fig. 5). Stepchildren were ill more frequently than their half siblings residing in the same household who were genetic offspring of both parents.

Family environment may be associated with child health for several reasons. First, household composition may affect physical

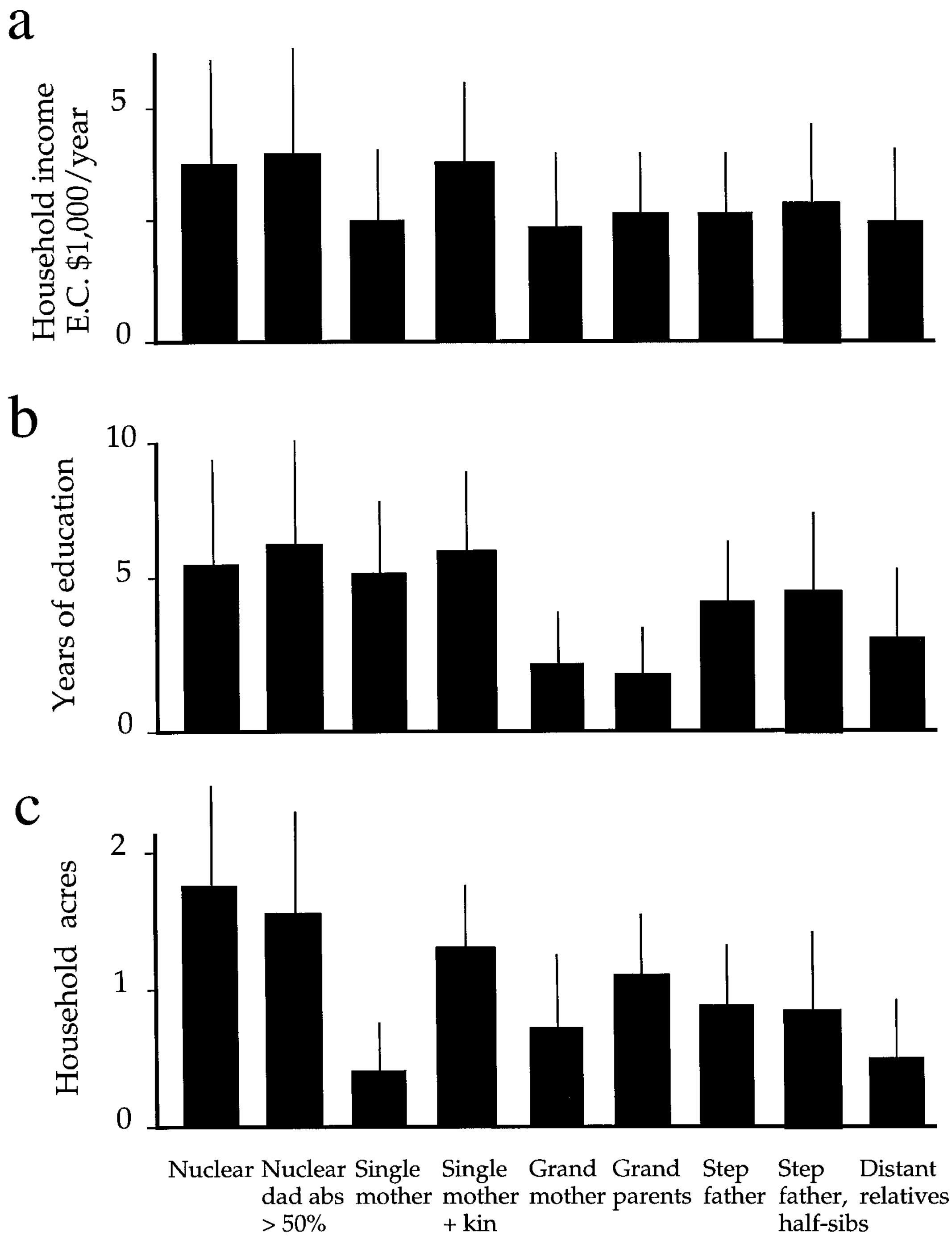

Fig. 3. SECs and family composition. Vertical bars represent 95% confidence intervals (1.96 SE). No significant differences exist for per capita household income. Grandparent households averaged fewer years of education. Single mother households had less land than biparental, single mother + kin, and grandparent households.

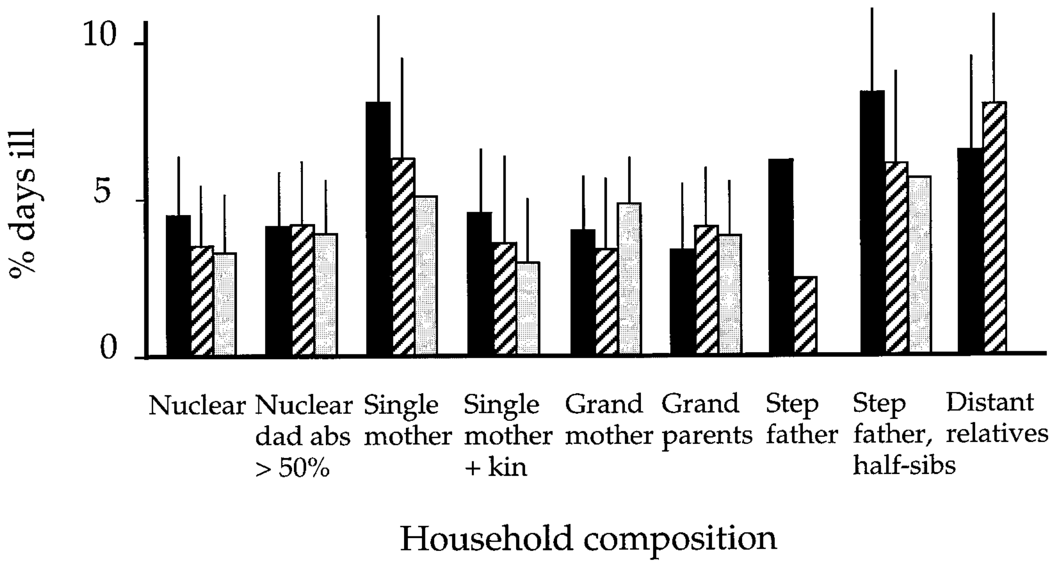

Fig. 4. SECs, household composition, and illness. Vertical bars represent 95% confidence intervals (1.96 SE) for groups with five or more children. Low, moderate, and high tertile SEC composite measures are represented by solid, hatched, and shaded bars respectively. Children living with single mothers, stepfather + half sibs, or distant relatives were ill more frequently than children living with both parents, single mother + kin, or grandparents. No significant SEC differences in frequency of illness within household composition type are evident.

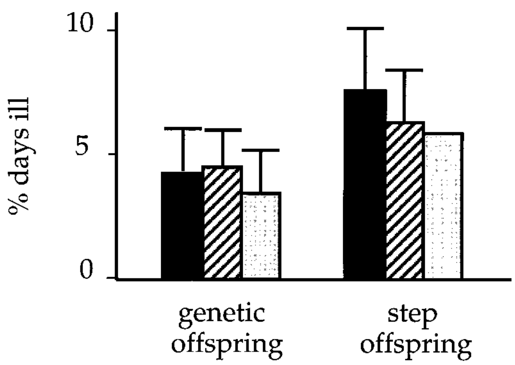

Fig. 5. SECs and frequency of illness among step- and genetic children residing in the same household. Low, moderate, and high tertile SEC composite measures are represented by solid, hatched, and shaded bars, respectively. In 34 of 43 dyads stepchildren had higher frequencies of illness than their coresident half siblings who were genetic offspring of both resident parents. Average age of stepchildren is 11.3 years, genetic children 8.4 years. Vertical lines for groups with five or more children show 95% confidence intervals.

aspects of caretaking (e.g., breast-feeding, bathing, protection from hazards, and general hygiene). Second, household composition may affect a child's psychosocial environment. In Bwa Mawego, marital conflict, residence change, and other potentially traumatic events were associated with household composition. Both physical and psychosocial aspects of a child's environment may affect stress and immune function.

Childhood stress is a key intermediate variable linking family environment, health, and socioeconomic conditions

Human infants and juveniles cannot survive, let alone develop effective social skills, without assistance from parents or other caretakers. Relationships within the caretaking household are essential for the developing child (Bowlby 1969, 1973). Composition of the family or caretaking household may have important effects on child development (Kagan, 1984; Whiting and Edwards, 1988). For example, in Western cultures, children with divorced parents may experience more emotional tension or stress than children living in a stable two-parent family (Wallerstein, 1983; Pearlin and Turner, 1987; Gottman and Katz, 1989).

Associations between average cortisol levels of children and household composition are presented in Figure 6. Children living

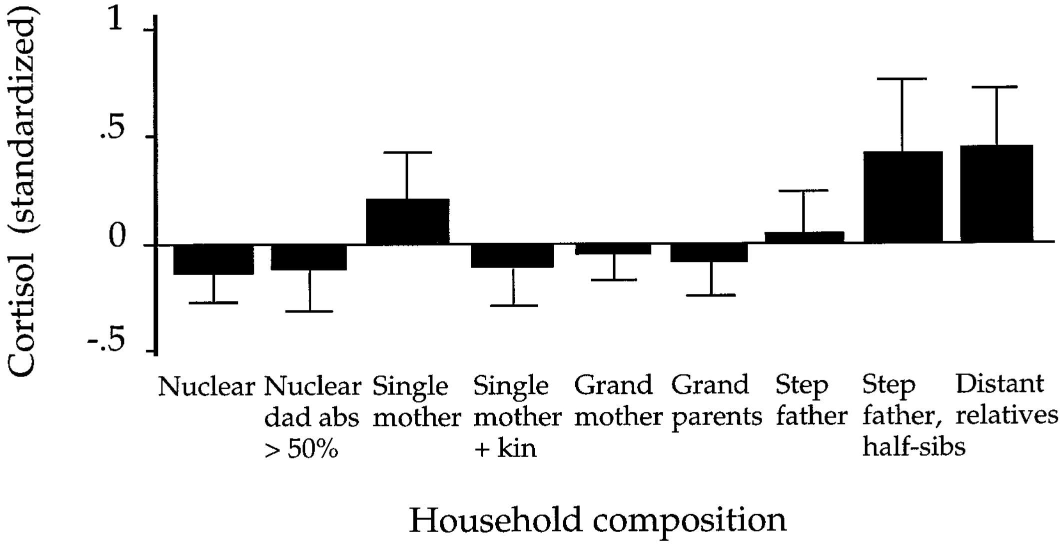

Fig. 6. Household composition and cortisol. Vertical bars represent 95% confidence intervals (1.96 SE). Sample sizes (number children, number cortisol saliva assays) are, respectively, as follows: 89, 6,905; 28, 2,234; 30, 2,296; 31, 2,581; 32, 2,645; 16, 1,341; 5, 279; 24, 1,870; 9, 482.

with nonrelatives, stepfathers + half siblings (stepfather has children by the stepchild's mother), or single parents without kin support had higher average levels of cortisol than children living with both parents, single mothers with kin support, or grandparents.[8] A further test of this hypothesis is provided by comparison of step and genetic children residing in the same households (Fig. 7). Step children had higher average cortisol levels than their half siblings residing in the same household who were genetic offspring of both parents.

We conclude from these data that childhood stress is associated with household composition. There are several possible reasons. Children in difficult caretaking environments may experience chronic stress resulting in moderate-high levels of cortisol (i.e., a child has cortisol levels that are above average day after day). They may experience more acute stressors that substantially raise cortisol for short periods of time. They may experience more frequent stressful events (e.g., parental chastisement or marital quarreling [see Wilson et al., 1980; Flinn, 1988; Finkelhor and Dzuiba-Leatherman, 1994]) that temporarily raise cortisol. There may be a lack of parental consolation or reconciliation. And they may have inadequate coping abilities, perhaps resulting from difficult experiences in early development. The following case examples present

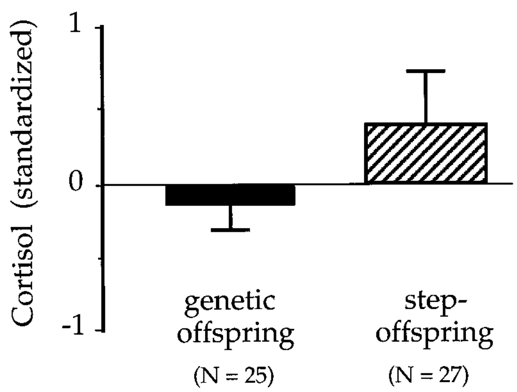

Fig. 7. Average (mean) cortisol levels of step and genetic children residing in the same household. In 38 of 43 dyads stepchildren had higher mean cortisol levels than their coresident half siblings who were genetic offspring of both resident parents. Average age of stepchildren was 11.3 years, genetic children 8.4 years. Vertical lines show 95% confidence intervals.

[8]The relation between cortisol levels and household composition for infants (1–14 months) is less certain. Preliminary analyses indicate infants in households without fathers had lower cortisol levels than infants in households with coresident fathers (Turner et al., 1995). However, this may reflect higher activity levels, different sleeping patterns, age effects, and/or more frequent breast-feeding among father-resident infants rather than higher levels of psychosocial stress.

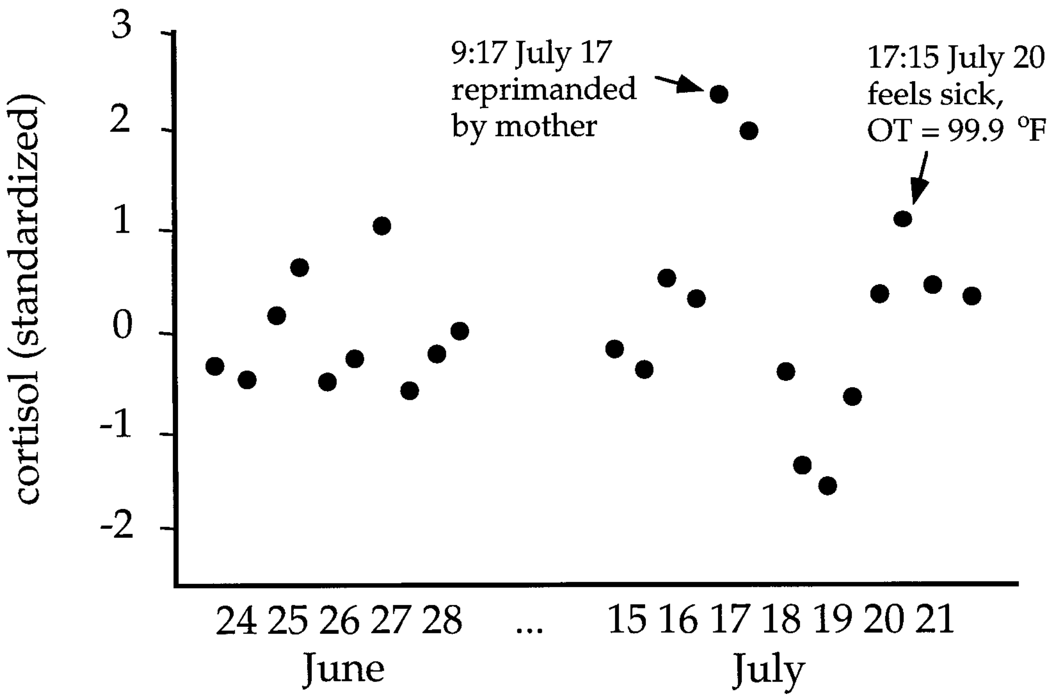

Fig. 8. Morning and afternoon cortisol levels of Jenny during summer 1994. Late June cortisol levels are normal, but, after being reprimanded by her mother on the morning of July 17, she had elevated cortisol levels for 1 day, followed by depressed cortisol levels for 2 days. Jenny exhibited symptoms of an upper respiratory illness with slight fever (common cold, probably rhinovirus) on the afternoon of July 20.

temporal analyses of family relations and cortisol levels that illustrate some of the above possibilities.

Jenny was a 12-year-old girl who lived with her grandparents, aunt, and uncle. Her mother had lived in Guadeloupe for the past 10 years. At 9:17 AM on July 17, 1994, I (M.V.F.) observed the following events. Wayonne, a 6-year-old male cousin who was visiting for the week, threw a stone at Jenny, who was sweeping in front of the house. She responded by scolding Wayonne, who pouted and retreated behind a mango tree. Wayonne found a mango pit and lobbed it towards Jenny but missed and hit a dress hanging on a clothesline, marking it with a streak of red dirt. Jenny ran to Wayonne, and struck him on the legs with her broom. He began to cry, arousing the interest of granny Ninee, who emerged from the cooking room, asked what happened, and, upon hearing the story, scolded Jenny for beating Wayonne. Jenny argued that she was in the right, but granny Ninee would not hear of it and sent her into the house. Jenny appeared frustrated but looked down and kept quiet despite a quivering lip.

Jenny's cortisol levels were substantially elevated that afternoon, followed by subnormal levels the next day (a possible recovery period?). Three days after the incident she reported feeling ill and had a runny nose and oral temperature of 99.9°F (Fig. 8).

On June 28, 1992, a serious marital conflict erupted in the Franklin household. Amanda was a 34-year-old mother of six children, five of whom (ages 2, 3, 5, 8, and 14) were living with her and their father/stepfather, Pierre Franklin. Amanda was angry with Pierre for spending money on rum. Pierre was vexed with Amanda for shaming him in front of his friends. He left the village for several weeks, staying with a relative in town. His three genetic children (ages 2, 3, and 5) showed abnormal cortisol levels for a prolonged period following their father's departure (Fig. 9). Children usually habituated to most stressful events, but

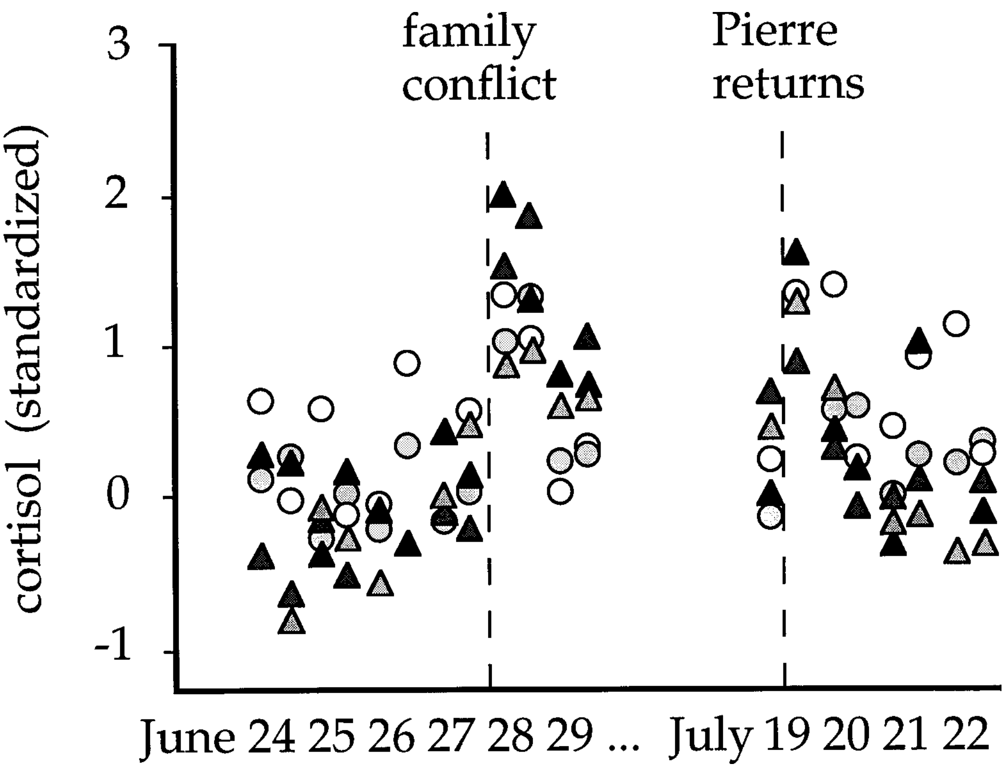

Fig. 9. Marital conflict and cortisol levels in the Franklin family. Three genetic children (2-, 3-, and 5-year-old males) are represented by lightly shaded, darkly shaded, and solid triangles, respectively, and two step children (8- and 14-year-old females) are represented by open and shaded circles, respectively. Cortisol levels of three genetic children were normal before the conflict, rose during the conflict and during father's absence, briefly rose upon his return, and returned to normal (lower) levels. The younger of the two stepchildren had a pattern of abnormally high cortisol, although her levels were moderate during the stepfather's absence. The older stepdaughter had a similar but more normal pattern of cortisol levels.

absence of a parent often resulted in abnormal patterns of elevated and/or subnormal cortisol levels. Following the return of their father, the Franklin children's cortisol levels resumed a more normal profile. Children living in families with high levels of marital conflict (observed and reported serious quarreling, fighting, residence absence) were more likely to have abnormal cortisol profiles than children living in more amiable families.

The events in children's lives that were associated with elevated cortisol are not always traumatic or even negative. Eating meals, hard physical work, routine competitive play such as cricket, basketball, and "king of the mountain" on ocean rocks, and the return of a family member who was temporarily absent (e.g., father returning from a job in town for the weekend) were associated with temporary moderate increases (about 10–100%) in cortisol among healthy children. These moderate stressors usually had rapid attenuation (<1 h) of cortisol levels (some stressors had characteristic temporal signatures of cortisol level and duration).

High stress events (cortisol increases from 100–2,000%), however, most commonly involved trauma from family conflict or change (Flinn and England, 1995; Flinn et al., 1996). Punishment, quarreling, and residence change substantially increased cortisol levels, whereas calm, affectionate contact was associated with diminished (−10 to −50%) cortisol levels. Of all cortisol values that were more than two standard deviations above mean levels (i.e., indicative of substan-

tial stress), 19.2% were temporally associated with traumatic family events (residence change of child or parent/caretaker, punishment, shame, serious quarreling, and/or fighting) within a 24 h period. Also, 42.1% of traumatic family events were temporally associated with substantially elevated cortisol (i.e., at least one of the saliva samples collected within 24 h was >2 S.D. above mean levels). Not all individuals had detectable changes in cortisol levels associated with family trauma. Nonetheless, traumatic family events were associated with elevated cortisol levels for all ages of children more than any other factor that we examined. These results indicate that family interactions were a critical psychosocial stressor in children's lives, although the sample collection during periods of intense family interaction (early morning and late afternoon) may have accentuated this association.

Although elevated cortisol levels are associated with traumatic events such as family conflict, long-term stress may result in diminished cortisol response. In some cases chronically stressed children had blunted response to physical activities that normally evoked cortisol elevation. Comparison of cortisol levels during nonstressful periods (no reported or observed crying, punishment, anxiety, residence change, family conflict, or health problem during the 24 h period before saliva collection) indicates a striking reduction and, in many cases, reversal of the family environment-stress association (Flinn and England, 1995). Chronically stressed children sometimes had subnormal cortisol levels when they were not in stressful situations. For example, cortisol levels immediately after school (walking home from school) and during noncompetitive play were lower among some chronically stressed children (cf. Long et al., 1993). Some chronically stressed children appeared socially tough or withdrawn and exhibited little or no arousal to the novelty of the first few days of the saliva collection procedure.

Concomitant with abnormal cortisol response is possible immunosuppression; some chronically stressed children appear to have reduced cell-mediated (neopterin, microglobulin β_2), humoral (secretory-immunoglobulin A), and/or nonspecific (neutrophil recruitment via interleukin-8) immunity (Flinn et al., 1995, in preparation). Stress response may deplete cellular energy and immune reserves (perhaps involving protection from autoimmunity). Although cortisol may provide short-term benefits, the body needs to replenish energy reserves to provide for immunity, growth, and other functions. Chronic stress and high average cortisol levels are associated with frequency of illness (Fig. 10), a stress—health relation suggested by temporal associations such as the above example of Jenny (Fig. 8), in which illness follows several days after a high stress event (see also Mason et al., 1979; Cohen et al., 1991, 1993; Stone et al., 1992; Evans and Pitt, 1994; Boyce et al., 1995). This association between illness and cortisol is significant within as well as among households (Flinn et al., 1992).

Longitudinal analysis of caretaking histories indicates that children may have sensitive periods for development of stress response. Children with severe caretaking problems during infancy (neglect, parental alcoholism, and/or maternal absence) and/or growth disruptions (weight loss of >10% of body weight) during the first 2 years of life (see black dots in Fig. 10) usually exhibit one of two distinct cortisol profiles: 1) unusually low basal cortisol levels with occasional high spikes or 2) chronically high cortisol levels. The first type (low basal, high spikes) is associated with hostility and antisocial behavior (e.g., theft, running away from home) and is more common among males. The second type (chronically high) is associated with anxiety and withdrawal behavior and is more common among females. These profiles are suggestive of diminished glucocorticoid regulatory function of the hippocampus (cf. Gray, 1987; Sapolsky, 1991; Yehuda et al., 1991; McBurnett et al., 1991).

Some children exhibit longitudinal change in cortisol profiles concomitant with an improved family environment, but others do not. Unlike many other potential stressors, most children do not seem to habituate readily to family trauma. Some parental actions may lack predictability and controlability necessary for development of actions or perceptions that reliably alleviate stress

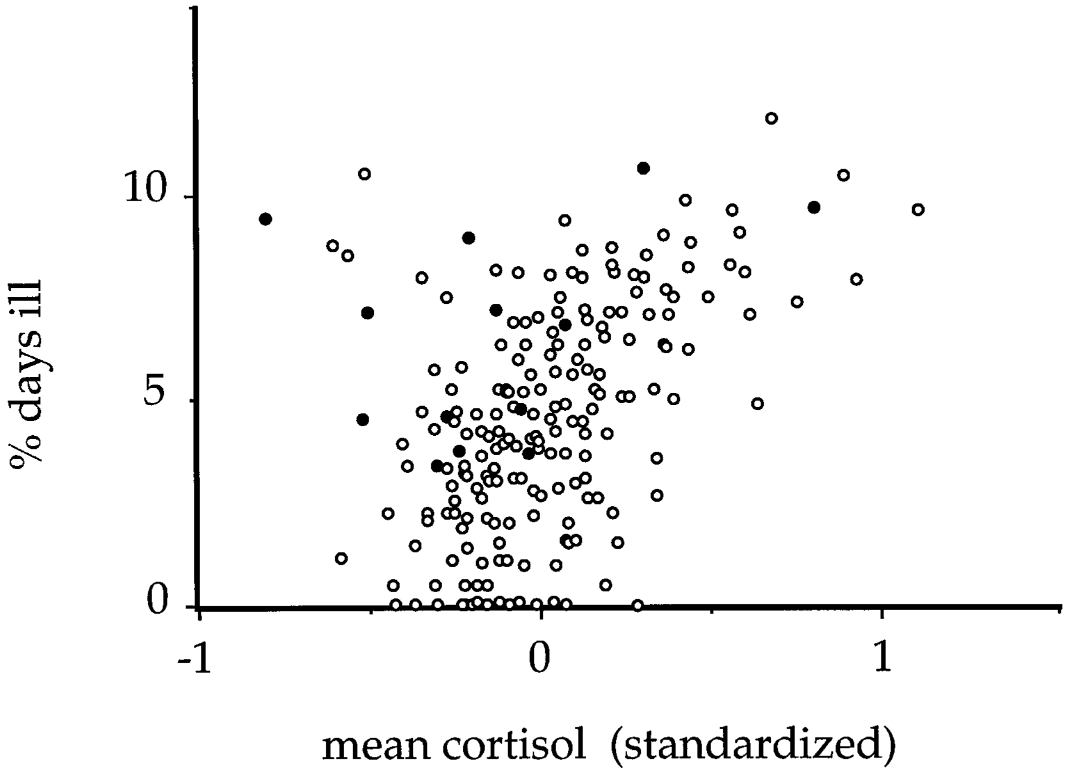

Fig. 10. Children's average cortisol levels were associated with frequency of illness (primarily upper respiratory infections with visible symptoms—runny nose, sore throat, cough, and/or fatigue) during 11 months of direct observation. Samples collected when the child was ill were excluded from computation of average cortisol values because cortisol levels tend to be higher during illness (Flinn and England, 1994). The sample includes children with more than 50 days of observation and more than 50 salivary cortisol measures. $R = 0.346$, $P < .01$. Black circles indicate children with significant growth disruptions (less than tenth percentile WHO weight for age or loss of more than 10% body weight) during the first 2 years of life.

response (Garmezy, 1983; Robins, 1983; Rutter, 1983; Hinde and Stevenson-Hinde, 1987).

SUMMARY AND CONCLUDING REMARKS

Glucocorticoid stress response may be viewed as an adaptive mechanism that allocates energy resources to different bodily functions, including immunity, growth, muscle action, and cognition (Maier et al., 1994; Sapolsky, 1994; McEwen, 1995). Understanding the algorithms by which stress response allocation decisions are made is important because of consequences for health and psychological development (Tinbergen, 1974).

The family is the most critical source of physical and social resources for children. Throughout human evolutionary history, parents and close relatives provided calories, protection, and information necessary for survival, growth, health, social success, and eventual reproduction (Alexander, 1974; Konner, 1981; Lancaster and Lancaster, 1987). The human mind is likely to have evolved special sensitivity to interactions with family caretakers, particularly during infancy and early childhood (Petrovich and Gewirtz, 1985; Belsky et al., 1991; Daly and Wilson, 1988, 1995; Baumeister and Leary, 1995). Release of cortisol and other stress hormones in response to traumatic family events may modulate energy and mental activity to resolve perceived psychosocial problems but may diminish immunity and other health functions.

The objective of our long-term ethnographic study in Bwa Mawego is to monitor children's social and physical environment,

behavioral activities, health, mental perceptions, and physiological states in a naturalistic setting to better understand relations among family environment, stress responses, and health. Analyses of data indicate that children living in households with intensive, stable caretaking usually had moderate cortisol levels (Figs. 6, 7) and low frequency of illness (Figs. 4, 5, 10). Children living in households with nonintensive, unstable caretaking were more likely to have abnormal (usually high and variable but sometimes low) cortisol levels. Traumatic family events were associated temporally with elevated cortisol levels (Fig. 9). Some children with caretaking and growth problems during infancy had unusual cortisol profiles. These associations indicate that family environment was a significant source of stress and illness risk for children living in Bwa Mawego. The variability of stress response, however, suggests a complex mix of each child's perceptions, neuroendocrinology, temperament, and specific context.

Relations between family environment and cortisol stress response appear to result from a combination of factors, including frequency of traumatic events, frequency of positive affectionate interactions, frequency of negative interactions such as irrational punishment, frequency of residence change, security of attachment, development of coping abilities, and availability or intensity of caretaking attention. Probably the most important correlate of household composition that affects childhood stress is maternal care. Mothers in socially secure households (i.e., permanent amiable coresidence with mate and/or other kin) appeared more able and more motivated to provide physical, social, and psychological care for their children. Mothers without mate or kin support were likely to exert effort attracting potential mates and may have viewed dependent children as impediments to this. Hence, coresidence of the father may provide not only direct benefits from paternal care but also may affect maternal care (Lamb et al., 1987; Lancaster, 1989; Belsky et al., 1991; Flinn, 1992; Hurtado and Hill, 1992). Young mothers without mate support usually relied extensively upon their parents or other kin for help with childcare.

Children born and raised in household environments in which mothers have little or no mate or kin support were at greatest risk for abnormal cortisol profiles and associated health problems. Because SECs influence family environment, they have consequences for child health that extend beyond direct material effects. And because health in turn may affect an individual's social and economic opportunities, a cycle of poor health and low SECs may be perpetuated generation after generation.

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